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For. **SEMICONDUCTOR OPTICAL DEVICE APPARATUS**

VERIFIED TRANSLATION OF PRIORITY DOCUMENT

Commissioner for Patents
Washington, D.C. 20231

December 5, 2002

Sir:

Enclosed is a verified English-language translation of priority document JP 11-045123. The enclosed document is referenced in the concurrently submitted Response under 37 C.F.R. § 1.111.

Respectfully submitted,

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Attachment: Verified English-language Translation of Priority Document JP 11-045123

DECLARATION

I, Junji Kamata, Patent Attorney, of SIKs & Co., 8th Floor, Kyobashi-Nisshoku Bldg., 8-7, Kyobashi 1-chome, Chuo-ku, Tokyo 104-0031 JAPAN hereby declare that I am the translator of the certified official copy of the documents in respect of an application for a patent filed in Japan on February 23, 1999 under Patent Application No. 045123/1999 and that the following is a true and correct translation to the best of my knowledge and belief.

Dated: November 22, 2002

Junji KAMATA

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This is to certify that the annexed is a true copy of the following application as filed with this office.

Date of Application: February 23, 1999

Application Number: Patent Application No. (Hei) 11-045123

Applicant(s): Mitsubishi Chemical Corporation

February 14, 2000

Takahiko KONDO

Commissioner, Patent Office

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[Title of the Invention]	Semiconductor Light Emitting Apparatus
[Number of Claims]	7
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[Document's Nam]	Specification 1
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[Document Name] Specification

[Title of the Invention] Semiconductor Light Emitting Apparatus

[Clams]

1. A semiconductor light emitting apparatus at least comprising, on a substrate:

a compound semiconductor layer containing an active layer;

a protection film having a stripe-shaped opening formed on the compound semiconductor layer; and

a ridge type compound semiconductor layer having a smaller refractive index than the refractive index of the active layer, the ridge type compound semiconductor layer being formed as to cover the stripe-shaped opening,

wherein the width of the stripe-shaped opening has a shape narrower at an opening end than at an opening center.

2. The semiconductor light emitting apparatus according to claim 1, wherein the width of the stripe-shaped opening has a portion gradually increasing as coming closing to the opening end from the opening center.

3. The semiconductor light emitting apparatus according to claim 1 or claim 2, wherein the width of the stripe-shaped opening is approximately unchanged around the opening end.

4. The semiconductor light emitting apparatus according to any one of claims 1 to 3, wherein the width of the stripe-shaped opening at the opening end is no less than 0.5 micron meter and no more than 10 micron meters.

5. The semiconductor light emitting apparatus according to any one of claims 1 to 4, wherein no protection film is formed on a ridge top and a side surface of the ridge type compound semiconductor layer.

6. The semiconductor light emitting apparatus according to any one of claims 1 to 5, wherein a contact layer is formed to cover a ridge top and a side surface of the ridge type compound semiconductor layer.

7. The semiconductor light emitting apparatus according to any one of claims 1 to 6, wherein a crystal growth plane of the substrate is (100) plane or its crystallographically equivalent plane, and wherein a longitudinal direction of a stripe-shaped opening of the protection film is [01-1] direction or its crystallographically equivalent direction.

[Detailed Description of the Invention]

[0001]

[Field of the Invention]

This invention relates to a semiconductor light emitting apparatus having a suitable structure for a ridge waveguide type semiconductor laser with a small beam spot diameter.

[0002]

[Description of Prior Art]

A structure so-called as a ridge waveguide type is frequently used to easily produce semiconductor light emitting apparatuses. Fig. 4 shows a manufacturing method for such a structure. First, an n-type clad layer 402, an active layer 403, a p-type clad layer 404, and a p-type contact layer 405 are formed on a substrate 401. Subsequently, a photoresist 408 having stripe openings as a pattern made by photolithography is formed on a wafer surface to form a stripe-shaped ridge by a wet etching process using the photoresist as a mask so that the p-clad layer remains with a prescribed thickness. A protection film 409 having insulating property is formed on the whole wafer surface; the protection film at a top of the ridge is removed by photolithography; and a p-side electrode 410 and an n-side electrode 411 are formed. The ridge structure thus formed can make the transverse mode for laser oscillation stabilized and can reduce the threshold currents.

[0003]

However, with such a conventional manufacturing method for ridge waveguide type semiconductor light emitting apparatus, because the ridge portion is formed by an etching, it is difficult to control the thickness of the clad layer in a non-ridge portion 511 with high accuracy. As a result, slight differences in the thickness of the clad layer in the non-ridge portion make the effective refractive index greatly deviated at that portion, thereby making the laser property of the semiconductor light emitting apparatus deviated and improvements in product yields not easily obtainable.

[0004]

To solve such a problem, a method has been proposed in which the thickness of the clad layer of the non-ridge portion is determined using a crystal growth rate during the crystal growth, in which a protection film is formed at the non-ridge portion, and in which the ridge portion is re-grown (see generally, JP-A-5-121,822, JP-A-9-199,791, JP-A-10-326,934, JP-A-326,935, JP-A-10-326,936, JP-A-326,937, JP-A-326,938, JP-A-10-326,945). Fig. 5 shows producing method and structure for such a laser device. When the ridge portion is formed, a layer is selectively re-grown in using a protection film 506 as a mask on stripe shaped openings 507, and a p-type second clad layer 508 and a p-type contact layer 509 are sequentially accumulated with trapezoid cross-sectional shapes according to isotropic nature in the growth rate with respect to face orientation. With this method, the thickness of the p-type first clad layer 504 in the non-ridge portion can be controlled with high accuracy, so that the effective refractive index can be controlled easily.

[0005]

However, the semiconductor light emitting apparatus thus manufactured by this

method also raises a problem. For example, the ridge waveguide type laser as set forth in JP-A-5-121,822 should have a ridge width around one micron at the ridge top if an optical waveguide structure is manufactured to achieve a single fundamental transverse mode. Consequently, because the contact area between the contact layer and the electrode becomes so small, the contact resistance between the contact layer and the electrode may increase, and laser characteristics and reliability may be deteriorated due to oxidized surfaces of the clad layer at the ridge side wall. Therefore, it is difficult to improve the product yield.

In the case of the ridge waveguide type laser as set forth in JP-A-199,791, because the bottommost portion of the ridge becomes in a reversed-mesa shape, the contact layer may not be formed, thereby raising problems such that the apparatus is easily oxidized and that the life time may be adversely affected. Since the electrode is not easily formed at the bottommost portion of the ridge, the interconnection may be cut, thereby creating a problem that the production yield is adversely affected. Therefore, it is demanded to provide a semiconductor light emitting apparatus with high reliability and good yield in manufacturing.

[0006]

Meanwhile, optical discs are made with a higher recording density these days, and according to this, light sources are developed vigorously. To make smaller the condensed spot diameter on a disc plate, practical use of red lasers (635 to 690 nm), instead of near infrared lasers (around 780 nm), begins, and blue semiconductor lasers having wavelength of around 400 to 420 nm, though in a stage of developments, are about to achieve longer lifetime in a CW operation. On the other hand, to focus the spot on the disc plate by condensing the laser beam, the laser beam is preferably formed in a shape closer to a circular shape, but actually, the beam divergence angle in a horizontal direction in a face parallel to the active layer is about one third in comparison with that in the vertical direction. Generally, a widened light intensity profile at the end face of the laser beam emission in the transverse direction causes the divergence angel in the horizontal direction to be small. A beam having an divergence in a shape closer to a circular shape can be obtained by narrowing the width of the stripe-shaped openings and by making the optical intensity profile at the emission end surface small, but the narrowed width of the stripe shaped openings increases current injections density to the active region, thereby promoting bulk deterioration, and raising a problem that the reliability of the device may be lowered. Particularly, in a material for short wavelength light source such as AlGaInP based, AlGaInN based, and MgZnSSe based materials, this problem becomes serious due to larger bulk deterioration caused by current injections in comparison with the conventional AlGaAs based material. If a beam closer to a circular shape is used, there are advantages such that the laser beam can be used with an improved efficiency (i.e., light amount cut by lenses becomes small) and any correction plate for beam shape becomes unnecessary. Therefore, it is demanded to

provide a semiconductor light emitting apparatus with a smaller beam spot diameter operable in keeping high reliability.

[0007]

To improve recording density of media such as a digital video disc as a center, a visible laser (generally, 630 to 690 nm) using an AlGaInP based material starts used practically as a light source for information processing instead of the conventional AlGaAs (wavelength is around 780 nm), but the following researches have been made to realize shorter wavelength, lower threshold, and high temperature operation.

In a production of an AlGaInP/GaInP based visible laser device, use of a substrate having an off-angle from the (100) plane toward the [011] direction (or [0-1-1] direction) allows to prevent the band gap from narrowing due to formation (ordering) of natural super lattices, thereby rendering the wavelength shorter readily, facilitating high concentration doping of p-type dopants (e.g., Zn, Be, and Mg), and improving the oscillation threshold current of the device by enhancement of the hetero-barrier and temperature characteristics. If the off-angle is too small, step bunching appears outstandingly, and large undulations are formed at the hetero-boundaries, so that a shift amount in which the PL wavelength (or oscillation wavelength) is shortened by quantum effects to the bulk active layer may be smaller than the designed amount where a quantum well structure (GaInP well layer of about 10 nm or less) is manufactured. If the off-angle is made lager, the step bunching is reduced, and the hetero-boundaries become flat, thereby making the wavelength shorter by the quantum effect as designed. Thus, a substrate having an off-angle of 8 to 16 degrees from the (100) plane toward the [011] direction (or [0-1-1] direction) is generally used to suppress formation of natural super lattices and generation of step bunching, which impede the wavelength from becoming shorter, as well as to suppress the oscillation threshold current from increasing due to shortened wavelength from p-type high concentration doping and impairment of temperature characteristics. A proper off-angel should be selected in consideration of thickness and the stress amount of the GaInP well layer depending on the targeted wavelength such as 650 nm or 635 nm. In a meantime, if a substrate having a large off-angle is used for shortening the wavelength, there raises a problem that the transversely asymmetry of the ridge shape in the ridge waveguide type laser may affect the transverse asymmetry of the light intensity profile.

[0008]

[Problems to be solved by the Invention]

Various technologies have been developed so far as described above, but the ridge waveguide type semiconductor light emitting apparatus still has a room to be improved, and waits for developments of improved technology. It is an object to provide a better semiconductor light emitting apparatus capable of solving the problems on the prior art as

described above. That is, it is an object of the invention to provide a semiconductor light emitting apparatus having a small beam spot diameter with high reliability and high production yield.

[0009]

[Means for solving the Problems]

The inventors, as a result of diligent research to solve the above problems, found out that a semiconductor light emitting apparatus can be made with a small beam spot diameter in keeping high reliability thereof where designing the width of a stripe shaped opening to have a shape narrower at an opening end (device end facet) than at an opening center (device center). They also discovered that formation of a contact layer as to cover a ridge portion and a side surface portion formed from re-growth to increase the contact area between the contact layer and an electrode, reduces the contact resistance and prevents a ridge side surface of the clad layer particularly including Al from oxidizing, thereby improving the laser property and reliability. Moreover, they discovered that, in a case where a substrate having a large off-angle to afford a short wavelength likewise AlGaInP/GaInP based visible laser, transversely asymmetric property of the ridge shape in the ridge waveguide type laser is little affected from the transverse asymmetry of the light intense profile, so that a stable basic transverse mode can be obtained up to a high output operation, and they came to provide this invention.

[0010]

That is, this invention is to provide a semiconductor light emitting apparatus having on a substrate at least a compound semiconductor layer containing an active layer, a protection film having a stripe-shaped opening formed on the compound semiconductor layer; and a ridge type compound semiconductor layer having a smaller refractive index than the refractive index of the active layer, the ridge type compound semiconductor layer being formed as to cover the stripe-shaped opening, wherein the width of the stripe-shaped opening has a shape wider at an opening end than at an opening center.

[0011]

As desirable embodiments of the semiconductor light emitting apparatus according to the invention, exemplified are: an embodiment having a portion in which the width of the stripe shaped opening gradually increases from the opening center to the opening end, an embodiment in which the width of the stripe shaped opening is approximately constant around the opening end, an embodiment in which no electrode is formed except the nearest portion of the end facet of the ridge type compound semiconductor layer, an embodiment in which the width of the stripe shaped opening is no less than 2 micron meters and no more than 1000 micron meters, an embodiment in which the compound semiconductor lay r including an activ layer has a layer of a refractive index smaller than that of the active layer on a substrate side of the active layer

(first conductivity type clad layer) and on a protection film side of the active layer (second conductivity type clad layer), respectively, an embodiment in which no protection film is formed on the ridge top and side surfaces of the ridge type compound semiconductor layer, an embodiment in which a distance between the active layer and the protection film is no less than 0.2 micron meter and no more than 0.5 micron meter, an embodiment in which a contact layer is formed as to cover the ridge top and side surfaces of the ridge type compound semiconductor layer, an embodiment in which a clad constituting the ridge type compound semiconductor layer is made of a clad containing Al, an embodiment in which the contact layer selects to cover the ridge top and side surfaces in a longitudinal direction of the stripe shaped opening, an embodiment in which a crystal growth plane of the substrate is (100) plane or its crystallographically equivalent plane and in which a longitudinal direction of a stripe-shaped opening of the protection film is [01-1] direction or its crystallographically equivalent direction, an embodiment in which a part of the ridge type compound semiconductor layer overlaps on the protection film, an embodiment in which an anti-oxidation layer constitutes a bottom of the stripe shaped opening where the anti-oxidation layer is formed on the second conductivity type first clad layer, an embodiment in which the surface of the substrate has an off-angle with respect to a low degree plane direction, and an embodiment in which a far field pattern has a single peak.

[0012]

[Embodiments of the Invention]

Hereinafter, referring to details of respective layers and an example of the manufacturing process, a semiconductor light emitting apparatus according to the invention is described specifically.

A method for growing a crystal during manufacturing the semiconductor light emitting apparatus according to the invention is not specifically limited, and known growing methods, such as MOCVD method or MBE method, can be used for crystal growth of a DH (double hetero) structure. The substrate used for the semiconductor light emitting apparatus according to the invention is not specifically limited as far as allowing a double hetero structure crystal to grow on the substrate. What is preferable is a conductive material, and desirably, the substrate is a crystal substrate made of, e.g., GaAs, InP, GaP, ZnSe, ZnO, Si, and Al_2O_3 suitable for growth of a crystal thin film on the substrate, more preferably, a crystal substrate having a zinc-blende structure. The crystal growth surface on the substrate is a low degree crystallographic plane or a crystallographically equivalent plane, more preferably a (100) plane.

In this specification, "(100) plane" is not necessary to be strictly a just (100) plane and can encompass cases that the substrate has an off-angle of 30° at most. In regard with the scale of the off-angle, the upper limit is preferably 30° or less, more preferably 16° or less,

whereas the lower limit is preferably 0.5° or greater, more preferably 2° or greater, further preferably 6°or greater, and most preferably 10° or greater.

[0013]

The substrate may be a hexagonal system substrate, and in such a case, Al_2O_3, 6H-SiC, etc. can be used.

The compound semiconductor layer containing an active layer, formed on the substrate, generally includes a layer having a refractive index smaller than the active layer on each of upper and lower sides of the active layer. A layer on the substrate side functions as a first conductive type clad layer, and a layer on the other side, or the epitaxial side, functions as a second conductive type clad layer. The compound semiconductor layer may contain a layer functioning as an optical guide layer.

The ridge type compound semiconductor layer containing the layer having a smaller refractive index than that of the active layer formed on the stripe shaped opening is generally made of a second conductive type second clad layer as a major portion. The compound semiconductor may contain a layer functioning as, e.g., an optical guide layer, other than the second conductive type second clad layer. The substantial whole surface of the ridge top and the side surface is preferably covered with a contact layer having a low resistance.

[0014]

The clad layer, the active layer, and the contact layer are not specifically limited, but it is preferable to use a general group III-V or II-VI semiconductor such as AlGaAs, AlGaInAs, AlGaInP, GaInAsP, AlGaInN, BeMgZnSe, MgZnSSe, and CdZnSeTe, and to produce a double hetero structure in which the active layer is sandwiched by the two clad layers. As a clad layer, a material having a smaller refractive index than that of the active layer is selected, and as a contact layer, a material having a narrower band gap than that of the clad layer is selected. As a proper carrier density of a low resistance to gain an ohmic contact with electrodes, the lower limit is preferably 1×10^{18} cm^{-3} or greater, more preferably, 3×10^{18} cm^{-3} or greater, most preferably, 5×10^{18} cm^{-3} or greater. The upper limit is preferably 2×10^{20} cm^{-3} or less, more preferably, 5×10^{19} cm^{-3} or less, most preferably, 3×10^{19} cm^{-3} or less. The active layer is not limited to a single layer and can be a single quantum well structure (SQW) composed of a quantum well layer and optical guide layers vertically sandwiching the quantum well layer or a multiple quantum well structure (MQW) composed of plural quantum well layers, barrier layers sandwiched between the quantum well layers, and optical guide layers respectively formed on the uppermost quantum well layer and under the lowermost quantum well layer.

[0015]

The protection film is not specifically limited but it is necessary to perform current injections only to a region of the active layer located below th ridge portion, which is formed at

a stripe shaped opening. That is, to confine currents by the protection film on both sides of the stripe shaped opening, the protection film has to be insulation. The refractive index of the protection film is preferably smaller than that of the clad layer to give effective refractive index difference between the ridge portion and the non-ridge portion in a transverse direction in the active layer and to stabilize the transverse mode of the laser oscillation. However, as a practical matter, if the refractive index difference is too large between the protection film and the clad layer, the second conductive type first clad layer below the ridge has to be thicker because the effective refractive index step in the transverse direction tends to be larger in the active layer, thereby increasing leak currents in the transverse direction. To the contrary, if the refractive index difference is too small between the protection film and the clad layer, the protection film has to be formed thicker to some extent since the light easily leaks outside the protection film, but this tends to impair the cleavage property. In consideration of those, together, the lower limit of the refractive index difference between the protection film and the clad layer is 0.2 or greater, more preferably, 0.3 or greater, and most preferably, 0.5 or greater. The upper limit is 3.0 or less, more preferably, 2.5 or less, and most preferably, 1.8 or less. There would be no problem, in regard with the thickness of the protection film, as far as the protection film can show a sufficient insulation property and has a thickness such that light does not come outside the protection film. The lower limit of the protection film is preferably 10 nm or greater, more preferably, 30 nm or greater, and most preferably, 50 nm or greater. The upper limit is preferably 500 nm or less, more preferably, 300 nm or less, and most preferably, 200 nm or less.

[0016]

The protection film is preferably a dielectric, and more specifically, can be selected preferably from a group of SiN_x film, SiO_2 film, SiON film, Al_2O_3 film, ZnO film, SiC film, and amorphous Si film. The protection film is used as a mask for formation of the ridge portion through a re-growth using an MOCVD method and is also used for the purpose of current squeezing. For simplifying the process, it is preferable to use a film having the same composition commonly for current squeezing and for selective growth, but layers having different compositions may be formed as a multilayer when necessary.

Where a zinc-blende type substrate is used and where the substrate surface is a (100) plane or its crystallographically equivalent plane, it is preferable that the longitudinal direction of the stripe shaped opening (the extending direction of the stripe) is extending in a [01-1] direction or its crystallographically equivalent direction to readily grow a contact layer, as described below, on the ridge top and the side surface. At that time, the most portion of the ridge side surface becomes (311)A plane in many cases, and it is possible to grow a contact layer on substantially the whole surface, on which a layer can be grown, on the second

conductive type second clad layer forming the ridge. This tendency is particularly remarkable when the second conductive type second clad layer is AlGaAs, particularly, AlGaAs having an AlAs content of 0.2 to 1.0, preferably, 0.3 to 0.9, more preferably, 0.4 to 0.8. The off-angel direction may be preferably within ± 30° from a direction perpendicular to the longitudinal direction of the stripe shaped opening, more preferably a direction within ± 7°, and further more preferably within ± 2°. The longitudinal direction of the stripe shaped opening is preferably, a [0-11] direction or a crystallographically equivalent direction in the case where the crystallographical plane of the substrate is (100), and the off-angle direction is preferably within ± 30° from a [0-11] direction or a crystallographically equivalent direction, more preferably a direction within ± 7°, and further more preferably within ± 2°. It is to be noted that in this specification, "[01-1] direction" indicates that the [01-1] direction is defined so that in general for III-V group or II-VI group semiconductor, the [11-1] surface existing between the (100) plane and the [01-1] plane becomes a plane at which the V group element or the VI group element appears.

[0017]

The semiconductor light emitting apparatus of the invention is not limited to an embodiment having the stripe shaped opening extending in the [01-1] direction. Hereinafter, other embodiments are described. Where the stripe shaped opening extends in the [011] direction or its crystallographically equivalent direction, the growth rate can be made anisotropically in association with, e.g., the growth condition, so that the rate is fast on the (100) plane whereas almost no growth is made on the (111)B plane. At that time, if the growth is made selectively on a (100) plane of the stripe shaped opening, a ridge shaped second conductive type second clad layer is formed with the (111)B plane as a side surface. In such a case, when the contact layer is subsequently formed, the contact layer is formed entirely on the ridge top made of the (100) plane as well as on the surfaces of the ridge top and the side surface made of the (111)B plane, by selecting conditions for creating more isotropic growth.

From substantially the same reason, when a wurtzite type substrate is used, as a direction that the stripe region can extend, it is preferable to use, e.g., [11-20] or [1-100] direction on (0001) plane. For HVPE (Hydride Vapor Phase Epitaxy), any direction can be used, and for MOVPE, [11-20] direction is preferable.

[0018]

When the semiconductor light emitting apparatus of the invention is designed, the thickness of the active layer and the composition of the clad layer are first determined to obtain a desired vertical divergence angle. If the vertical divergence angle is made narrower, light encroachment from the active layer to the clad layer is promoted, thereby reducing the optical density at the end facet, and improving the optical damage (COD) level at the light emission

surface. Accordingly, when a high output operation is necessary, though the vertical divergence angle is set relatively narrow, there is a limitation, as for a lower side, to suppress increase of the oscillation threshold currents due to reduction of light confinement in the active layer and reduction of the temperature characteristics due to overflow of carriers. The lower limit is preferably 15° or higher, more preferably 17° or higher, and further more preferably 19° or higher. The upper limit is preferably 30° or lower, more preferably 27° or lower, and further more preferably 25° or lower.

When a vertical divergence angle is determined, structural parameters greatly controlling a high output characteristics are a distance dp between the active layer and the protection film and a width W (hereinafter referred to as "stripe width") of the stripe shaped opening when seen in a vertical direction to the compound semiconductor layer. Generally, between the active layer and the protection film only the second conductive type first clad layer exists, and in such a situation, the distance dp is a thickness of the second conductive type first clad layer. When the active layer has a quantum well structure, the distance between the active layer closest to the protection film and the protection film becomes numeral dp. To realize lasers with achievements of high output operation and with beam closer to a circular shape in maintaining high reliability, it is necessary to set the distance dp and the width W in a proper range with good controllability.

[0019]

To realize a beam close to a circle, it is effective to narrow the stripe width, but injection current density turns into an unfavorable state from a viewpoint to suppress the bulk deterioration. Therefore, reduction of beam spot and low operation current operation can be realized at the same time, and high reliability can be maintained, where the center width W2 of the stripe shaped opening serving as a gaining region is made relatively broad whereas the end width W1 is made relatively narrow. That is, an end (cleavage surface) width W1 preferably has an upper limit of 10 μm or less, more preferably 5 μm or less, and further more preferably 3 μm or less, and a lower limit of 0.5 μm or greater, and more preferably 1 μm or greater. As for the center width W2, the upper limit is preferably 100 μm or less, more preferably 50 μm or less. The lower limit is preferably 1 μm or greater, more preferably 1.5 μm or greater, and further more preferably 2.2 μm or greater. Differences between the end width W1 and center width W2 have an upper limit of 100 μm or less, more preferably 50 μm or less. The lower limit is preferably, 0.2 μm or greater, more preferably 0.5 μm or greater.

[0020]

To render the transverse mode a single mode (having a light intensity profile in the transverse direction with a single peak), the stripe width cannot be made so large from viewpoints to cut off higher degree modes and to prevent hole burning from occurring, so that

an upper limit of the end width W1 is preferably 5 μm or less, more preferably 4 μm or less. The center width W2 preferably has an upper limit of 6 μm or less, more preferably 5 μm or less. In regard to the differences between the end width W1 and center width W2, the upper limit is preferably 5 μm or less, more preferably 3 μm or less, and further more preferably 2 μm or less. The lower limit is preferably 0.2 μm or greater, more preferably 0.5 μm or greater.

[0021]

The stripe shaped opening preferably has a portion gradually increasing or decreasing the stripe width from the center to the end. The end desirably has a portion with an unchanged stripe width. Those lengths of the gradually increasing or decreasing portions and the portion with the unchanged stripe width can be determined as appropriate for characteristics targeted by the semiconductor light emitting apparatus. The lengths of the gradually increasing or decreasing portions are, from a viewpoint to reduction of waveguide loss, preferably 5 to 10 μm, more preferably 10 to 50 μm. The length of the portion of the unchanged stripe width is, from a viewpoint to accuracy in cleavage, preferably 5 to 30 μm, more preferably 10 to 20 μm. The stripe shaped opening may be produced according to necessity as follows:

(1) Asymmetric openings where the stripe width and/or length of the portion with the unchanged stripe width and/or the gradually increasing or decreasing portions are not the same with respect to the respective end of the chip;

(2) Openings having no unchanged width portion but having width gradually increasing or decreasing up to the end;

(3) Openings where one end (typically, a front end facet as the light emission side for high output) is only formed with the stripe width gradually increasing or decreasing;

(4) Openings having a front end facet and a rear end facet different from each other in regard to the stripe width at the end; and

(5) Opening having a combination of some of (1) to (4).

[0022]

It is effective to suppress bulk deterioration due to current injection to the stripe shaped opening around the end and to reduce recombination currents at each end in avoiding formation of any electrode around each end for facilitating production of a laser having a small beam spot with high reliability.

In general, when a stripe width in the semiconductor layer is determined by etching (particularly, wet etching), if the stripe width is made gradually increasing or decreasing, the edge of the stripe changes stepwise due to fuzziness on the stripe edge because some specific plane selectively comes out readily, this stepwise undulation at the edge readily causes disorders such as ripples in the far field pattern in the horizontal direction, a larg side peak, and the like. On the other hand, with a desirable embodiment of the invention, because the stripe width

gradually increasing or decreasing portions are formed by etching of SiNx amorphous film, the stripe width can be increased or decreased linearly, so that an isolated single peak can be formed easily without ripple or side peak.

[0023]

With respect to the distance dp, an upper limit is preferably 0.60 μm or less, more preferably 0.50 μm or less, further more preferably 0.45 μm or less, and still further more preferably 0.40 μm or less. A lower limit is preferably 0.10 μm or greater, more preferably 0.15 μm or greater, and further more preferably 0.20 μm or greater. It is particularly recommended that dp is 0.25 μm to 0.45 μm. However, the above optimum range may be shifted depending on the use object (such as settings of divergence angle, etc.) and materials (such as refractive index, resistance, etc.). With respect to the optimum range, it should be noticed that the above structural parameters may affect each other.

It is to be noted that if the second conductive type second clad layer is structured of a III-V group compound semiconductor containing Al such as AlGaAs, it is preferable to use a III-V group compound semiconductor not containing Al such as GaAs to cover substantially the entire surface to which the crystal can be grown because the compound semiconductor prevents the surface from oxidizing.

[0024]

When the semiconductor light emitting apparatus according to the invention is manufactured, after forming a double hetero structure is formed, a ridge type second conductive type second clad layer and a second conductive type contact layer are selectively grown using a protection film, and it is preferable to form electrodes on the ridge top and the side surfaces without forming a protection film on the ridge top and the side surfaces. The specific conditions for growing the respective layer may vary depending on the layer's composition, growing method, shape of the apparatus, etc., and in a case that a compound semiconductor of group III-V is grown by the MOCVD method, preferably, the double hetero-structure is formed at a growing temperature of about 650 to 750 °C with a V/III ratio of about 20 to 60 (in the case of AlGaAs) or about 350 to 550 (in the case of AlGaInP), whereas the ridge portion is formed at a growing temperature of 600 to 700 °C with V/III ratio of about 40 to 60 (in the case of AlGaAs) or about 350 to 550 (in the case of AlGaInP). Where the ridge portion selectively grown in use of the protection film contains, particularly, Al such as in AlGaAs and AlGaInP, it is very preferable if a very small amount of an HCl gas is introduced during the growth, because the gas prevents polycrystals from depositing. However, as the Al is contained much more in the composition, or as the ratio of the mask portion to the opening is higher, a necessary introduction amount of HCl increases for making a selective growth only on the opening (selectiv mode) in preventing polycrystals from depositing where other growing conditions are

unchanged. On the other hand, if the HCl gas is introduced too much, the AlGaAs layer may not be grown, and conversely, although the semiconductor layer is etched (etching mode), a necessary introduction amount of HCl increases for entering to the etching mode as the Al is contained much more in the composition, even where other growing conditions are unchanged. The optimum introduction amount of HCl greatly depends on a molecular number of the group III source supply including Al such as trimethylaluminum or the like. More specifically, the ratio of the supply molecular number of HCl to group III source supply molecular number including Al (HCl / Group III) is preferably 0.01 or more, more preferably 0.05 or more, and further more preferably 0.1 or more. An upper limit is preferably 50 or less, more preferably 10 or less, and further more preferably 5 or less. It is to be noted that ridge component control tends to be difficult when a compound semiconductor layer containing In at the ridge is selectively grown (particularly, HCl introduction).

[0025]

The preferred semiconductor light emitting apparatus according to the invention includes, on a substrate, at least a compound semiconductor layer containing an active layer, a protection film having a stripe shaped opening formed on the layer, a ridge type compound semiconductor layer having a smaller refractive index than that of the active layer on the stripe shaped opening, and a contact layer formed on substantially the entire surface of the ridge shape, and the semiconductor light emitting apparatus can realize a high output operation where the width of the stripe shaped opening is set from 2.2 μm to 1,000 μm, and the resistance of the entire apparatus can be reduced to a low value by creating an adequate contact area between the contact layer and the electrodes adjacent to the contact layer and the second conductive type clad layer. A portion of the ridge top and side surfaces on which the contact layer is formed can be covered with a protection film for the purpose of preventing the layer from oxidizing or the like. In this embodiment, the apparatus can have a lower resistance in comparison with an apparatus formed with a protection film without forming any contact layer on the ridge side surface, and falls within the scope of the invention. It is particularly effective to reduce the resistance of the entire apparatus where a material having a high specific resistance such as AlGaInP based and AlGaInN based (especially, of p-type).

[0026]

In another preferred embodiment of the invention, a portion of the ridge type compound semiconductor layer having a smaller refractive index than that of the active layer formed on the stripe shaped opening is formed as to overlap the protection film. The overlapped portion of the second conductive type second clad layer over the insulation film is 0.01 μm as a lower limit, more preferably 0.1 μm or greater, and as an upper limit, preferably less than 2.0 μm, and more preferably 1.0 μm or less. Use of such an embodiment improves

the controllability of the light profile encroaching around boundaries between the protection film and the ridge bottom, thereby reducing optical absorption at the contact layer formed on the ridge top and the side surfaces. If this embodiment is used, a protection film formed on the side surfaces of the ridge portion is not always necessary unlike the conventional ridge waveguide type laser, so that such use is advantageous for simplification of the processes and cost reduction. A structure not having any protection film made of an insulation on the ridge side surfaces is little influenced with undulations on the edges of the gradually increasing or decreasing portions of the stripe width because the ridge portion grows in the transverse direction. Accordingly, the semiconductor light emitting apparatus having such a structure can obtain a good single peak having no ripple or side peak in the far field pattern in the horizontal direction.

[0027]

With another preferable embodiment of the invention, the width of the stripe shaped opening is characterized in a size of 4 μm or less, and this feature allows the transverse mode to be a single mode (light intensity profile in the transverse direction having a single peak).

The semiconductor light emitting apparatus of the invention can form the far field pattern to be a single peak, so that the apparatus can be used to provide a desirable laser for broad applications such as information processing and optical telecommunication.

The semiconductor light emitting apparatus of the invention can have a clad layer formed between the active layer and the protection film, and where the thickness of the clad layer is set to 0.10 μm or greater or 0.50 μm or less, a high output operation can be realized easily with the width of the stripe shaped opening.

In the semiconductor light emitting apparatus of the invention, where the protection film is made of a dielectric such as SiN_x film, SiO_2 film, SiON film, Al_2O_3 film, ZnO film, SiC film, and the like, the apparatus can readily realize a high output operation under the above condition. At that time, it is preferable to set the refractive index difference between the protection film and the second conductive type first clad layer at the oscillation wavelength equal to or higher than 0.5 and equal to or less than 2.0.

[0028]

The height (thickness) of the second conductive type second clad layer is preferably set to about 0.25 to 2.0 times of the width W of the stripe shaped opening as described above. If within this range, it is preferable because the second conductive type second clad layer would not be projected so much in comparison with the current block layer or ridge dummy layer as described below, because the device life would not be affected due to stresses exerted to the ridge portion when the d vic is used in a manner of the junction down, and because post processes such as a forming process for el ctrodes are done easily since it is very low in

comparison with its vicinity.

With the invented semiconductor light emitting apparatus, a clad in the ridge shape is formed by re-growth where an antioxidant layer is formed on a side of epitaxial surface of the DH structure, thereby easily preventing a high resistance layer, which may increase a passage resistance at re-growth boundaries from occurring.

As the antioxidant layer, there is no special limitation on selection of the material as far as it is hardly oxidized or it is cleaned up easily. More specifically, a compound semiconductor layer of III-V group having a low containing rate of readily oxidized elements such as Al (about 0.3 or less) is exemplified. It is preferable that the antioxidant layer does not absorb light from the active layer by selecting the material or thickness of the antioxidant layer to avoid the operation current from increasing. The material of the antioxidant layer can be ordinarily selected from materials having a wider band gap than that of the active layer material, but a material, even where its band gap is narrow, can be used where the thickness is 50 nm or less, preferably, 30 nm or less, more preferably, 10 nm or less because light absorbing can be substantially neglected.

[0029]

With the embodiment, the profile controllability of light otherwise encroaching adjacent regions between the protection film and the ridge is made better where the clad layer of the re-growth portion is grown as to be over the top of the protection film; the side surface of the clad layer is prevented from oxidizing by growing the contact layer on substantially the whole surface on which a crystal can be grown on the re-grown clad layer; the contact resistance to the electrode may be reduced by increasing the contact area in contact with the electrode on a side of the epitaxial surface. The steps for growing the re-growing clad layer and the contact layer coming over the protection film can be done independently or done in combination. Where the ridge is formed by re-growth, a ridge dummy layer may be formed which has a larger area than the ridge portion subjecting to current injection and in which no current injection is made in order to improve the composition of the ridge portion and the controllability of the carrier concentration and growth rate. In this situation, an insulation covering layer such as an oxide layer or a thyristor structure is formed at a portion of the ridge dummy layer to prevent the current from passing. Where the current injection stripes are formed on the off-angled substrate in a perpendicular direction as much as possible to the off direction, although the ridge of the re-growth becomes transversely asymmetric, the light profile that comes out the vicinity of the protection film and the ridge has a good symmetry, because the refractive index difference between the protection film and the clad layer of the ridge portion is easily made larger than the conventional block layer made of a semiconductor layer as shown in Fig. 6, and because the clad layer of the re-growth portion can be grown as to cover the top surface of the

protection film by selecting the stripe direction properly, and therefore, this apparatus can obtain a fundamental transverse mode oscillation which is stable even at a high output stage. Thus, this invention is applicable to various ridge stripe type waveguide structure semiconductor light emitting apparatuses.

[0030]

In accordance with the preferred embodiment of the invention, the refractive index of the second conductive type first clad layer is larger than the refractive index of the second conductive type second clad layer. Therefore, this can suppress expansion of the light profile (near field pattern) to the ridge portion, thereby achieving improvements in symmetry of the vertical divergence angle (far field pattern), suppression of side peaks of horizontal divergence angle (far field pattern), and improvements in laser property by suppressed light absorption at the contact layer and in the reliability.

With another preferred embodiment of the invention, the antioxidant layer is formed at least right below the stripe shaped opening on the second conductive type first clad layer, or namely, at the stripe shaped opening and, preferably, on the opposite sides of the stripe shaped opening. This may prevent a high resistance layer that may increase the passing resistance from occurring on the re-growth boundary where the clad layer of the ridge portion is formed by re-growth. If impurities such as oxygen exist in a large amount at the re-growth boundary, light absorption (heating) at the boundary due to lowered crystal quality and promotion of impurity diffusions through lattice defects may be induced, thereby inviting impairments on property and reliability.

[0031]

This invention is applicable to various semiconductor light emitting apparatuses, and the apparatus according to the invention can be combined with various embodiments as exemplified below.

(1) An apparatus formed with a current block layer such as a semiconductor or dielectric on the outer side of the protection film constituting the opposite sides of the stripe shaped opening to improve cleavage and yield during assembling and rendering the life time longer by reducing stresses in the ridge portion when the apparatus is assembled with a junction down state.

(2) An apparatus capable of self-excited oscillating by setting the width of the stripe shaped opening and the distance between the active layer and the protection film in a proper range and by forming the vertical divergence angle of the light in a specific range.

(3) An apparatus formed with a structure having a ridge dummy region on an outer side of the protection film constituting the opposite sides of th stripe shaped opening to readily control the thickness of the stripe shaped opening, the composition, and the carrier

concentration.

As a semiconductor laser apparatus to which this invention applies, the light source for information processing (typically, AlGaAs based (wavelength about 780 nm), AlGaInP based (wavelength 600 nm band), InGaN based (wavelength about 400 nm) are described, but this invention is also applicable to broad use (particularly, high output operation) such as a semiconductor laser apparatus for telecommunication, other than the above, e.g., a signal light source laser for telecommunication (typically, having an active layer made of InGaAsP or InGaAs, 1.3 μm band, 1.5 μm band), a light source laser for fiber excitation (about 980 nm using an InGaAs strained quantum well active layer / GaAs substrate, about 1480 nm using an InGaAsP strained quantum well active layer / InP substrate). The laser having a spot close to a circle, even for telecommunication, is advantageous to the extent of raising the coupling efficiency with fibers.

[0032]

[Embodiments]

Hereinafter, examples and comparative examples are described to illustrate the invention in detail. The material, concentration, thickness, manipulation order, and the like indicated in the following examples are properly changeable as far as not goes beyond the spirit of the invention. Accordingly, the scope of the invention is not limited to the detailed examples shown in the following examples.

[0033]

[Example 1]

In this example, a semiconductor light emitting apparatus according to the invention having a cross-sectional structure shown in Fig. 1(c) was manufactured.

On an n-type GaAs substrate 101 ($n=1x10^{18}$ cm^{-3}) having a thickness of 350 μm and a major surface of (100) plane, an n-type clad layer 102 having a thickness of 2.0 μm made of a Si doped $Al_xGa_{1-x}As$ ($x = 0.55$, $n = 1 \times 10^{18}$ cm^{-3}); a double quantum well (DQW) active layer 106 in which an optical guide layer 103 having a thickness of 10 nm made of an undoped $Al_xGa_{1-x}As$ ($x = 0.35$), a well layer 104 having a thickness of 8 nm made of an undoped $Al_xGa_{1-x}As$ ($x = 0.10$), a barrier layer 105 having a thickness of 5 nm made of an undoped $Al_xGa_{1-x}As$ ($x = 0.35$), a well layer 104 having a thickness of 8 nm made of an undoped $Al_xGa_{1-x}As$ ($x = 0.10$), and an optical guide layer 103 having a thickness of 10 nm made of an undoped $Al_xGa_{1-x}As$ ($x = 0.35$) are accumulated sequentially; a p-type first clad layer 107 having a thickness of 0.30 μm made of a Zn doped $Al_xGa_{1-x}As$ ($x = 0.55$, $p = 1 \times 10^{18}$ cm^{-3}); an antioxidant layer 108 having a thickness of 10 nm made of a Zn doped $Al_xGa_{1-x}As$ ($x = 0.2$, $p = 1 \times 10^{18}$ cm^{-3}) were accumulated orderly by an MOCVD method to form a double hetero-structure (Fig. 1(a)).

Subsequently, a SiN_x protection film 109 was deposited by 200 nm on the surface f the

double hetero substrate. Many stripe shaped openings 110 were opened in this SiN_x film by a photolithographic method in extending in a [01-1] direction. The stripe shaped opening was subject to patterning during the laser chip manufacturing process so that the width of the stripe shaped opening became 3 μm, constant, at a center (W 2), gradually increasing towards each end, and 4 μm, constant, at each end (cleavage facet, W1) as shown in Fig. 3. The length at the center portion was 400 μm; the length of the gradually increasing portion was 30μm on each side; the length of the end with the unchanged width was 20 μm on each side.

A p-type second clad layer 111 made of a Zn doped p-type $Al_xGa_{1-x}As$ ($x = 0.60$, $p = 1 \times 10^{18}$ cm^{-3}) having a height of 2.0 μm at a ridge center was formed on the stripe shaped opening 110 by selective growth using an MOCVD method (Fig. 1(b)). The p-type second clad layer appeared to have a ridge shape in which a (311) A plane was a main facet. Subsequently, p-type contact layer 112 made of a Zn doped GaAs having a carrier concentration 1×10^{19} cm^{-3} was formed thereon by selective growth using an MOCVD method. This contact layer was grown almost isotropically on the ridge shaped p-type second clad layer 111 and formed as the p-type contact layer 112 having a thickness of 0.5 μm as to cover the entire ridge surface (Fig. 1(b)).

[0034]

With the above MOCVD method, trimethyl gallium (TMG) and trimethyl aluminum (TMA) were used for raw materials for III group source, and arsine was used for raw materials for V group, where hydrogen was used for carrier gas. Dimethyl zinc (DEZ) was used for the p-type dopant, and disilane was used for the n-type dopant. Moreover, when the ridge is grown, the HCl gas is introduced at a molecular ratio of HCl / group III of 0.12, particularly, 0.22 as a molecular ratio of HCl / TMA.

From SEM observation, the ridge shaped p-type second clad layer was confirmed as formed in about 0.4 μm in covering the protection film made of SiNx as shown in Fig. 1. Although the undulation on a ridge side wall was made a little larger at the gradually increasing portion of the stripe width, the layer was confirmed as formed in about 0.4 μm in covering the protection film at that region. The contact layer covered the whole surface of the ridge side wall at every stripe width. This could prevent the ridge shaped p-type second clad layer from being exposed on a surface and oxidized at the surface. There would be no problem to cover a part or the whole surface of the ridge side wall with a SiNx protection film likewise in a conventional method, but in this example, no protection film made of dielectric or the like was formed on the ridge side surface in consideration of simplification of processing, reduction of contact resistance, etc.

[0035]

Subsequently, a p-type electrode 113 was deposited. After the substrate was made

thinner to 100 μm, an n-type electrode 114 was deposited on the substrate and was alloyed (Fig. 1(c)). A laser resonator structure was formed by cutting into chip bars by cleavage from the wafer thus produced. The length of the resonator was set to 500 μm at that time. After an asymmetric coating of 10 % on the front end side and 90 % on the rear end side was made, the bar was separated into each chip by secondary cleavage.

After assembled in a manner of the junction down, characteristics of current vs. optical output, current vs. voltage were measured under continuous wave (CW) at 25 °C. Very good characteristics of current vs. optical output, current vs. voltage were shown, and the threshold value was 1.7 V, a low value corresponding to a bandgap of the active layer, as a confirmation of non-existence of any high resistance layer. A series resistance was small, 4 to 5 Ω, and it was confirmed that the contact resistance between the p-type contact layer and the p-type electrode was very small. The laser of this example could obtain a high output up to optical output 150 mW operation, have very good property such that the oscillation wavelength was 785 nm in average; the threshold current was 20 mA in average; the slope effectiveness was 1.0 mW/mA in average. The laser had a vertical divergence angle of 20° in average during the optical output of 50 mW and obtained the single peak far field pattern (beam divergence angle) as exactly designed, and it was confirmed that the optical profile can be controlled very well. The horizontal divergence angle was 10° in average at the optical output of 50 mW, can be made in a size half of approximately the vertical divergence angle, and came closer to a circle than that of the conventional high output laser. Therefore, optical loss in an optical system can be reduced, and the laser property when assembled as an optical pickup and the assembling yield became very good since the optical axis adjustment in the horizontal direction is easily made. A good single peak with no ripple or side peak was obtained in the far field pattern in the horizontal direction. This may suggest that factors are not only that the stripe width is increased straight but also that the laser was little affected from the ridge undulation of the gradually increasing portion of the stripe width because the ridge portion was grown laterally. It is to be noted that in this specification, "a single peak" does not necessarily mean that it allows a sole peak but means that no other peak having an intensity one tenth of the maximum peak intensity exists. According to those results, the laser structure of the invention is useful for light source for writing to optical discs such as CD-R, MD, etc. In addition, it was turned out that the structure had high reliability (stable operation for 1000 hours or more under high output of 100 mW, high temperature of 60°C). Moreover, in this example, it was confirmed that the respective devices of each batch or between the batches had less deviation in device property.

[0036]

Where the stripe width was made broader than the above example, it was turned out

that the almost all devices did not oscillate with a single transverse mode (single peak in light intensity profile in the transverse direction) when the stripe width at the center reached 5 μm or grater. This indicates that it is desirable to set the stripe width to be 5 μm or less to realize the single transverse mode oscillation.

As a result upon confirmation through a simulation of a region operable for high output based on the experimental results, it was turned out that the effective refractive index gap in the transverse direction in the active layer should be set around 5×10^{-3} to 1.3×10^{-2}.

[0037]

[Example 2]

A chip was manufactured according to substantially the same steps as in Example 3, and the laser was assembled in a manner of the junction-down. However, a multiple quantum well (MQW) active layer including an optical guide layer having a thickness of 8 nm made of an undoped $Al_xGa_{1-x}As$ (x = 0.35) and six well layers made of an undoped $Al_xGa_{1-x}As$ (x = 0.10) was formed, and a p-type first clad layer made of a Zn doped $Al_xGa_{1-x}As$ (x = 0.55; $p = 1 \times 10^{18}$ cm^{-3}) having a thickness of 0.35 μm was formed. The stripe shaped opening was subject to patterning so that the width of the stripe shaped opening became 2 μm, constant, at a center W2, gradually decreasing towards each end, and 1 μm, constant, at each end W1 (cleavage facet). At that time, the length at the center portion was 150 μm; the length of the gradually decreasing portion was 30μm on each side; the length of the end with the unchanged width was 20 μm on each side. Except the length of the resonator in which the ridge top of the p-type second clad layer made of a Zn doped $Al_xGa_{1-x}As$ (x = 0.60; $p = 1 \times 10^{18}$ cm^{-3}) was 1.5 μm in height was 250 μm, and except a symmetric coating of 32 % on both of the front end and the rear end was made, the chip was experimentally produced by the same process as in Example 1.

[0038]

The laser of this example could achieve self-excited oscillation up to operation of an optical output of 10 mW or greater, and had very good property such that the oscillation wavelength was 785 nm in average; the threshold current was 20 mA in average; the slope effectiveness was 0.6 mW/mA in average. The laser had a vertical divergence angle of 30° in average during the optical output of 5 mW and obtained the single peak far field pattern (beam divergence angle) as exactly designed, and it was confirmed that the optical profile can be controlled very well. The horizontal divergence angle was 15° in average during the optical output of 5 mW and was about a half of the vertical divergence angle, which came closer to a circle more than a conventional high output laser. With respect to the far field pattern in the horizontal direction, a good single peak with no ripple or side peak was obtained. This may suggest that factors are not only that the stripe width is decreas d straight but also that the laser was little affected from the ridge undulation of the gradually decreasing portion of the stripe

width because the ridge portion was grown laterally. According to those results, the laser structure of the invention is useful for light source for reading for optical discs such as CD, MD, etc. In addition, it was turned out that the structure had high reliability (stable operation for 1000 hours or more under output of 8 mW, high temperature of 80°C). Moreover, in this example, it was confirmed that the respective devices of each batch or between the batches had less deviation in device property.

[0039]

Where the center width W2 of the stripe shaped opening was made broader than the above example, it was turned out that the almost all devices did not oscillate by self-excitation when the width reached 3 μm or grater. This indicates that it is desirable to set the center width W2 of the stripe shaped opening to be less than 3 μm to realize the self-excited oscillation.

As a result upon confirmation through a simulation of a region in which the center width W2 of the stripe shaped opening and the thickness dp of the second conductive type first clad layer satisfy the self-excited oscillation condition, it was turned out that the effective refractive index gap in the transverse direction in the active layer should be set around 2×10^{-3} to 7×10^{-3} and that light encroaching rate $T_{ACT.OUT}$ to the respective ridge sides should be set to around 10 to 40 %.

[0040]

[Example 3]

In this example, a semiconductor light emitting apparatus according to the invention having a cross-sectional structure shown in Fig. 2(c) was manufactured.

On a GaAs substrate 201 having a thickness of 350 μm and an off-angle of about 10 ° to 15° in a [0-1-1]A direction from (100) plane, first, a Si doped n-type GaAs buffer layer ($n = 1 \times 10^{18}$ cm^{-3}), which is not shown in Fig.2, having a thickness of 0.5 μm, an n-type first clad layer 202 made of a Si doped $Al_{0.75}Ga_{0.25}As$ ($n = 1 \times 10^{18}$ cm^{-3}) having a thickness of 1.5 μm, an n-type second clad layer 203 made of a Si doped $(Al_{0.7}Ga_{0.3})_{0.5}In_{0.5}P$ ($n = 1 \times 10^{18}$ cm^{-3}) having a thickness of 0.2 μm, a triple quantum well (TQW) active layer 207 made of (three layers) an undoped $Ga_{0.44}In_{0.56}P$ well layer 205 having a thickness of 5 to 6 nm sandwiched by an optical guide layers 204 made of an undoped $(Al_{0.5}Ga_{0.5})_{0.5}In_{0.5}P$ having a thickness of 50 nm or a barrier layers 206 made of an undoped $(Al_{0.5}Ga_{0.5})_{0.5}In_{0.5}P$ having a thickness of 5 nm, a p-type first clad layer 208 made of a Zn doped $(Al_{0.7}Ga_{0.3})_{0.5}In_{0.5}P$ ($p = 7 \times 10^{17}$ cm^{-3}) having a thickness of 0.25 μm, a Zn doped p-type $Ga_{0.5}In_{0.5}P$ antioxidant layer 209 ($p = 1 \times 10^{18}$ cm^{-3}) having a thickness of 5 nm were accumulated orderly by an MOCVD method to form a double h tero-structure (Fig. 2(a)). At that time, the antioxidant layer preferably has a selected composition so as not to absorb light generated by re-combinations in the active layer in order

to reduce the threshold current, but can be used as an over-saturation absorbing layer upon absorbing light intentionally to do self-pulsation. It is further effective to change the composition of the $Ga_xIn_{1-x}P$ antioxidant layer with Ga rich side (X = 0.5 to 1) or to add Al in a small amount ($(Al_xGa_{1-x})_{0.5}In_{0.5}P$, X = approximately 0.1 to 0.2) to prevent the light from being absorbed.

[0041]

Subsequently, a SiN_x protection film 210 as an insulator (having a refractive index 1.9 and wavelength 650 nm) was deposited by 200 nm on the surface of the double hetero substrate. Many stripe shaped openings 211 were opened in the SiN_x film 210 by a photolithographic method in a [01-1] B direction, which is perpendicular to the off-angle direction. In a general III-V group compound semiconductor, a [01-1]B direction is defined so that the (11-1) plane located between the (100) plane and the (01-1) plane is a plane where the V group element appears. The stripe shaped opening was subject to patterning during the laser chip manufacturing process so that the width of the stripe shaped opening became 4 μm, constant, at a center W2, gradually increasing towards each end, and 5 μm, constant, at each end W1 (cleavage facet) as shown in Fig. 3(a). The length at the center portion was 300 μm; the length of the gradually increasing portion was 30μm on each side; the length of the end with the unchanged width was 20 μm on each side.

[0042]

A ridge made of a Zn doped p-type $Al_{0.75}Ga_{0.25}As$ clad layer 212 ($p = 1.5 \times 10^{18}$ cm^{-3}, refractive index 3.3, wavelength 655 nm) having a thickness or height of 2.0 μm at the ridge center and a Zn doped GaAs contact layer 213 having a thickness of 0.5μm, was formed on the stripe shaped opening 211 by selective growth using an MOCVD method (Fig. 2(b)). At that time most of the side surfaces of the ridge was (311) A plane or other planes close to the plane, and the clad layer of the re-growth portion was grown as to cover the top surface of the protection film serving as an insulator, thereby allowing the contact layer to grow on substantially the entire surface on which a crystal can grow on the clad layer of the re-growth portion. Therefore, the device can make better the controllability of the light profile which comes out the vicinity of the protection film and the ridge, can suppress the side surface of the clad layer from oxidizing, and can reduce the contact resistance with the electrode by increasing the contact area in contact with the electrode on the epitaxial surface side. This tendency is remarkable where the re-growth ridge is AlGaAs, particularly where the Al content of the AlAs compound crystal is set 0.2 to 0.9, preferably 0.3 to 0.8.

[0043]

With the above MOCVD method, trimethyl gallium (TMG), trimethyl aluminum (TMA), and trimethyl indium (TMI) were used for raw materials for III group sourc , and arsine

and phosphine were used for raw materials for V group, and hydrogen was used for carrier gas. Dimethyl zinc was used for the p-type dopant, and disilane was used for the n-type dopant. Moreover, when the ridge was grown, the HCl gas was introduced at a molecular ratio of HCl / group III of 0.2, particularly, 0.3 as a molecular ratio of HCl / TMA.

From SEM observation, the ridge shaped p-type second clad layer was confirmed as formed in about 0.4 μm in covering the protection film made of SiNx as shown in Fig. 2. The contact layer covered the whole surface of the ridge side wall at every stripe width. This could prevent the ridge shaped p-type second clad layer from being exposed on a surface and oxidized at the surface. There would be no problem to cover a part or the whole surface of the ridge side wall with a SiNx protection film likewise in a conventional method, but in this example, no protection film made of dielectric or the like was formed on the ridge side surface in consideration of simplification of processing, reduction of contact resistance, etc. The ridge shape became slightly asymmetric transversely, not shown, due to influence of the off-angle of the substrate.

[0044]

Subsequently, a p-type electrode 214 was deposited. After the substrate was made thinner to 100 μm, an n-type electrode 215 was deposited on the substrate and was alloyed (Fig. 2(c)). A laser resonator structure was formed by cutting into chip bars by cleavage from the wafer thus produced. The length of the resonator was set to 500 μm at that time. After an asymmetric coating of 10 % on the front end side and 90 % on the rear end side was made, the bar was separated into each chip by secondary cleavage.

After assembled in a manner of the junction down, characteristics of current vs. optical output, current vs. voltage were measured under continuous wave (CW) at 25 °C. Very good characteristics of current vs. optical output, current vs. voltage were shown, and the threshold value was 1.7 V, a low value corresponding to a bandgap of the active layer, as a confirmation of non-existence of any high resistance layer. A series resistance was small, 5 to 6 Ω, and it was confirmed that the contact resistance between the p-type contact layer and the p-type electrode was very small. The laser of this example could obtain a high output up to optical output 150 mW operation, have very good property such that the oscillation wavelength was 655 nm in average; the threshold current was 20 mA in average; the slope effectiveness was 1.0 mW/mA in average. The laser had a vertical divergence angle of 23° in average during the optical output of 50 mW and obtained the single peak far field pattern (beam divergence angle) as exactly designed, and it was confirmed that the optical profile can be controlled very well. The horizontal divergence angle was 10° in average at the optical output of 35 mW, can be made in a size half of approximately the vertical divergence angle, and came closer to a circle than that of th conventional high output laser. With respect to the far field pattern in the horizontal

direction, a good single isolated peak was obtained without any ripple or side peak. This is grounded on that not only the stripe width can be reduced linearly but also the gradually reduced portion in the stripe width is little affected from undulations of the ridge portion because the ridge portion grows in the lateral direction. From this result, it is assumed that no adverse effect comes out to kink levels or the like due to slight asymmetry of the re-grown ridge shape, since the transverse mode is basically controlled by the SiNx protection film. With respect to the horizontal divergence angle, and a good single peak with no ripple or side peak was obtained in the far field pattern in the horizontal direction. According to those results, the laser structure of the invention is useful for light source for writing to optical discs such as DVD or the like. In addition, it was turned out that the structure had high reliability (stable operation for 1000 hours or more under high output of 35 mW, high temperature of 60°C). Moreover, in this example, it was confirmed that the respective devices of each batch or between the batches had less deviation in device property.

[0045]

Where the stripe width was made broader than the above example, it was turned out that the almost all devices did not oscillate with a single transverse mode (single peak in light intensity profile in the transverse direction) when the stripe width at the center reached 5 μm or grater. This indicates that it is desirable to set the stripe width to be 5 μm or less to realize the single transverse mode oscillation.

As a result upon confirmation through a simulation of a region operable for high output based on the experimental results, it was turned out that the effective refractive index gap in the transverse direction in the active layer should be set around 5×10^{-3} to 1.3×10^{-2}.

[0046]

A chip was manufactured according to substantially the same steps as in Example 3. However, a quadruple quantum well (QQW) active layer including an optical guide layer having a thickness of 70 nm made of an undoped $(Al_{0.5}Ga_{0.5})In_{0.5}P$ and four well layers made of an undoped $Ga_{0.44}In_{0.56}P$ was formed, and a Zn doped p-type $(Al_{0.7}Ga_{0.3})_{0.5}In_{0.5}P$ clad layer($P = 7 \times 10^{17}$ cm^{-3}) having a thickness of 0.35 μm was formed. The stripe shaped opening was subject to patterning so that the width of the stripe shaped opening became 2.5 μm, constant, at a center W2, gradually decreasing towards each end, and 1.5 μm, constant, at each end W1 (cleavage facet). At that time, the length at the center portion was 250 μm; the length of the gradually decreasing portion was 30μm on each side; the length of the end with the unchanged width was 20 μm on each side. Except the length of the resonator in which the ridge top of the p-type second clad layer made of a Zn doped $Al_{0.75}Ga_{0.25}As$ ($p = 1.5 \times 10^{18}$ cm^{-3}; refractive index 3.3; wavelength 655 nm) was 1.5 μm in height was 350 μm, and exc pt an asymmetric c ating of 32 % on the front end and 80% on the rear end was made, the chip was experimentally produced

by the same process as in Example 3.

[0047]

The laser of this example could achieve self-excited oscillation up to operation of an optical output of 5 mW or greater, and had very good property such that the oscillation wavelength was 655 nm in average; the threshold current was 25 mA in average; the slope effectiveness was 0.5 mW/mA in average. The laser had a vertical divergence angle of 30° in average during the optical output of 5 mW and obtained the single peak far field pattern (beam divergence angle) as exactly designed, and it was confirmed that the optical profile can be controlled very well. The horizontal divergence angle was 15° in average during the optical output of 5 mW and was about a half of the vertical divergence angle, which came closer to a circle more than a conventional high output laser. With respect to the far field pattern in the horizontal direction, a good single peak with no ripple or side peak was obtained. This may suggest that factors are not only that the stripe width is decreased straight but also that the laser was little affected from the ridge undulation of the gradually decreasing portion of the stripe width because the ridge portion was grown laterally. According to those results, the laser structure of the invention is useful for light source for reading for optical discs such as CD, MD, etc. In addition, it was turned out that the structure had high reliability (stable operation for 1000 hours or more under output of 5 mW, high temperature of 70°C). Moreover, in this example, it was confirmed that the respective devices of each batch or between the batches had less deviation in device property.

[0048]

Where the center width W2 of the stripe shaped opening was made broader than the above example, it was turned out that the almost all devices did not oscillate by self-excitation when the width reached 3 μm or grater. This indicates that it is desirable to set the center width W2 of the stripe shaped opening to be less than 3 μm to realize the self-excited oscillation.

As a result upon confirmation through a simulation of a region in which the center width W2 of the stripe shaped opening and the thickness dp of the second conductive type first clad layer satisfy the self-excited oscillation condition, it was turned out that the effective refractive index gap in the transverse direction in the active layer should be set around 2×10^{-3} to 7×10^{-3} and that light encroaching rate $T_{ACT.OUT}$ to the respective ridge sides should be set to around 10 to 40 %.

[0049]

[Comparative Example]

A laser chip was manufactured with the same conditions as in Example 1 except that the width of the stripe shaped opening was set to 3 μm, unchanged, at the center and the ends.

After assembled in a manner of the junction-down, the laser property was measured under continuous wave (CW) at 25 °C, but at the optical output of 35 mW, the vertical divergence angle was 23° in average; the horizontal divergence angle was 8° in average; the horizontal divergence angle became smaller, one third of the vertical divergence angle, which indicated a beam in considerably an ellipse shape. Thus, the laser increased light loss in the optical system and rendered difficult the optical axis adjustment in horizontal direction, so that the laser property and assembling yield when the laser was assembled as an optical pickup were impaired.

[0050]

[Advantages of the Invention]

In accordance with the invention, upon designing the width of the stripe shaped opening to be smaller at the opening end than at the opening center, a laser can be formed with a beam spot close to a circle in keeping high reliability. Therefore, optical loss in an optical system can be reduced, and the laser property when assembled as an optical pickup and the assembling yield became very good since the optical axis adjustment in the horizontal direction is easily made.

According to the invention, a semiconductor light emitting apparatus having a structure having no protection film made of an insulator on the ridge side surface can be provided by forming a ridge type compound semiconductor layer at the stripe shaped opening to which current is injected by selective growth in use of a protection film made of an insulator. With this semiconductor light emitting apparatus, not only the stripe width can be reduced linearly, but also the gradually reduced portion in the stripe width is little affected from undulations of the ridge portion because the ridge portion grows in the lateral direction. Therefore, a good single isolated peak can be easily obtained without any ripple or side peak in the far field pattern in the horizontal direction.

[0051]

Moreover, according to the invention, by forming a contact layer as to cover the ridge top and side surfaces, a semiconductor light emitting apparatus can be provided with an increased contact area between the contact layer and the electrode. In use of such a structure, the contact resistance can be reduced, and laser property and reliability can be improved upon prevention of surface oxidation of the ridge side surface of the clad layer containing, particularly, Al. Moreover, when a substrate having a large off-angle with respect to some low degree plane direction such as (100) is used for rendering the wavelength shorter likewise the AlGaInP/GaInP based visible laser, the transverse symmetry of the light density profile (or beam profile) is good even where the ridge shape of the ridge waveguide type laser is in a transversely symmetric shape, so that the apparatus can be oscillated with a basic transverse

mode stable up to a high output operation and can be manufactured with a highly improved yield and high reliability.

Furthermore, the semiconductor light emitting apparatus also has an advantage to greatly improve the production yield because manufactured with simplified processes not using complicated and very fine photolithography as used conventionally.

[Brief Description of the Drawings]

[Fig. 1] It is a cross section illustrating a manufacturing process of a semiconductor light emitting apparatus of a first example.

[Fig. 2] It is a cross section illustrating a manufacturing process of a semiconductor light emitting apparatus of a third example.

[Fig. 3] It is a plan view illustrating width changes of a stripe-shaped opening at a resonator direction in a semiconductor light emitting apparatus according to the invention.

[Fig. 4] It is a cross section illustrating a manufacturing process of a conventional semiconductor light emitting apparatus whose ridge portion is formed by etching.

[Fig. 5] It is a cross section illustrating a manufacturing process of a conventional semiconductor light emitting apparatus in which a contact layer is formed on a ridge top.

[Fig. 6] It is a cross section illustrating a semiconductor light emitting apparatus having an inner-stripe structure of a ridge type or groove type using a current block layer made of a semiconductor.

[Description of Reference Numbers]

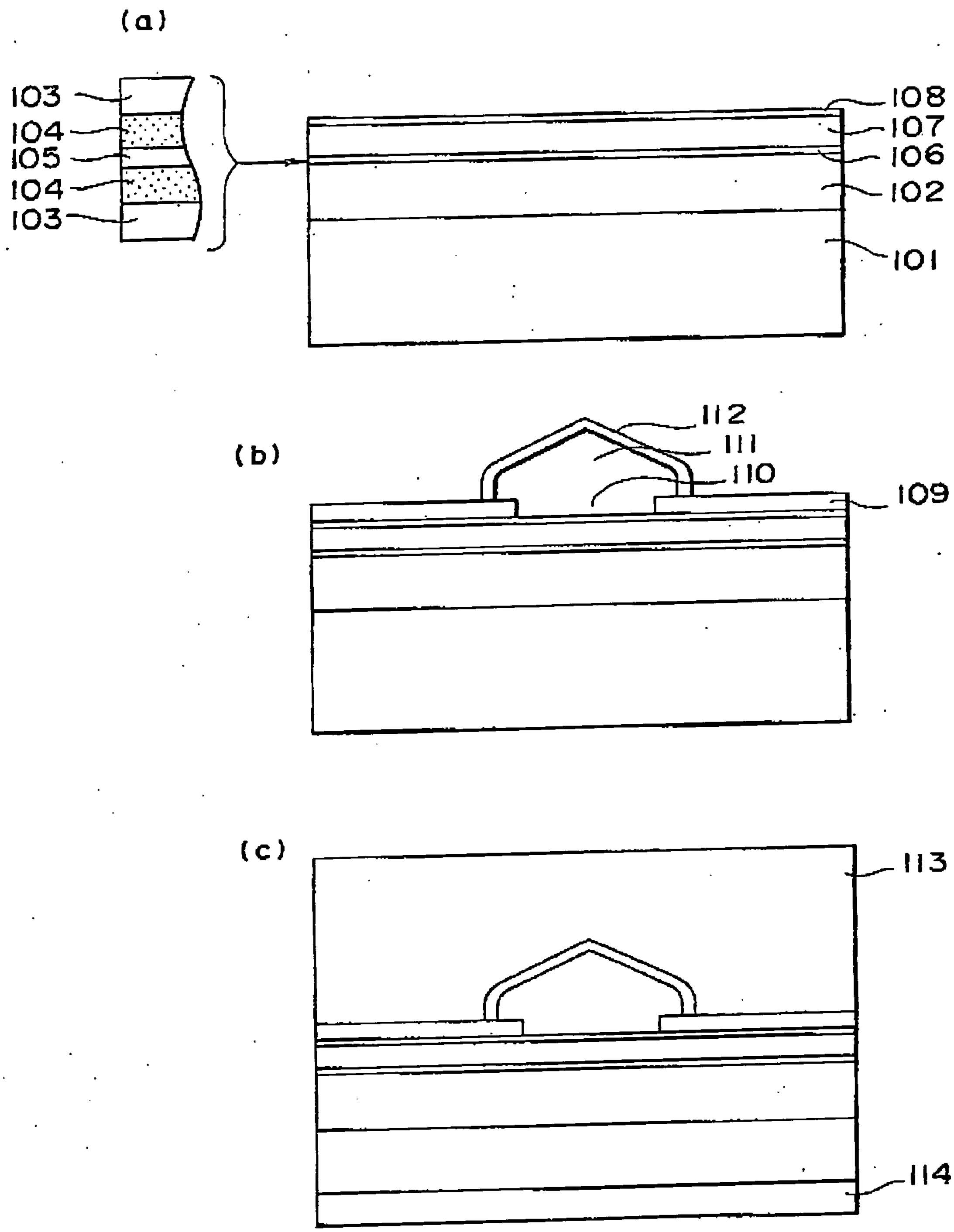
101 substrate
102 n-type clad layer
103 optical guide layer
104 well layer
105 barrier layer
106 active layer
107 p-type first clad layer
108 antioxidant layer
109 protection film
110 stripe shaped opening
111 p-type second clad layer
112 contact layer
113 p-type electrode
114 n-type electrode
201 substrate
202 n-type first clad layer

203 n-type second clad layer
204 optical guide layer
205 well layer
206 barrier layer
207 active layer
208 p-type first clad layer
209 antioxidant layer
210 protection film
211 stripe shaped opening
212 p-type second clad layer
213 contact layer
214 p-type electrode
215 n-type electrode
W1 end width
W2 center width
401 substrate
402 n-type clad layer
403 active layer
404 p-type clad layer
405 contact layer
406 non-ridge portion
407 ridge portion
408 resist
409 protection film
410 p-type electrode
411 n-type electrode
501 substrate
502 n-type clad layer
503 active layer
504 p-type first clad layer
505 antioxidant layer
506 protection film
507 stripe shaped opening
508 p-type second clad layer
509 contact layer
510 p-type electrode

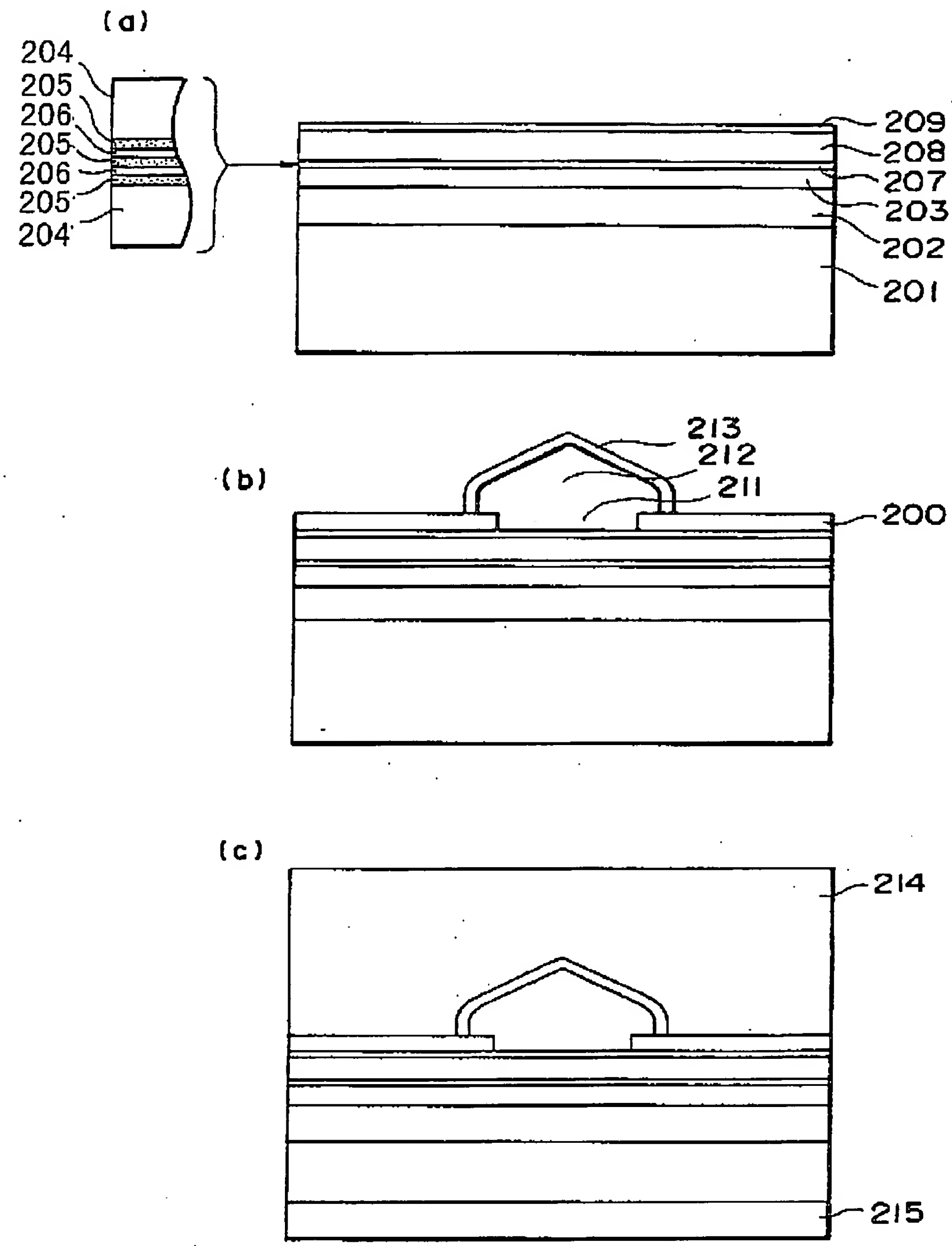
511 n-type electrode
601 substrate
602 first conductivity type clad layer
603 active layer
604 second conductivity type clad layer
605 first conductivity type current block layer
606 second conductivity type contact layer
607 epitaxial side electrode
608 substrate side electrode
611 substrate
612 first conductivity type clad layer
613 active layer
614 second conductivity type clad layer
615 first conductivity type current block layer
616 second conductivity type clad layer
617 second conductivity type contact layer
618 epitaxial side electrode
619 substrate side electrode

[Document Name] Drawings

[Fig.1]



[Fig.2]


(a)
204
205
206
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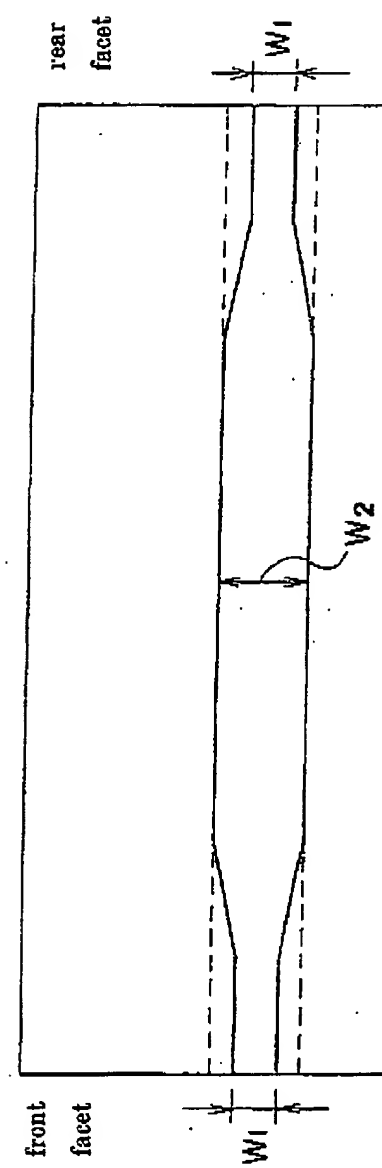
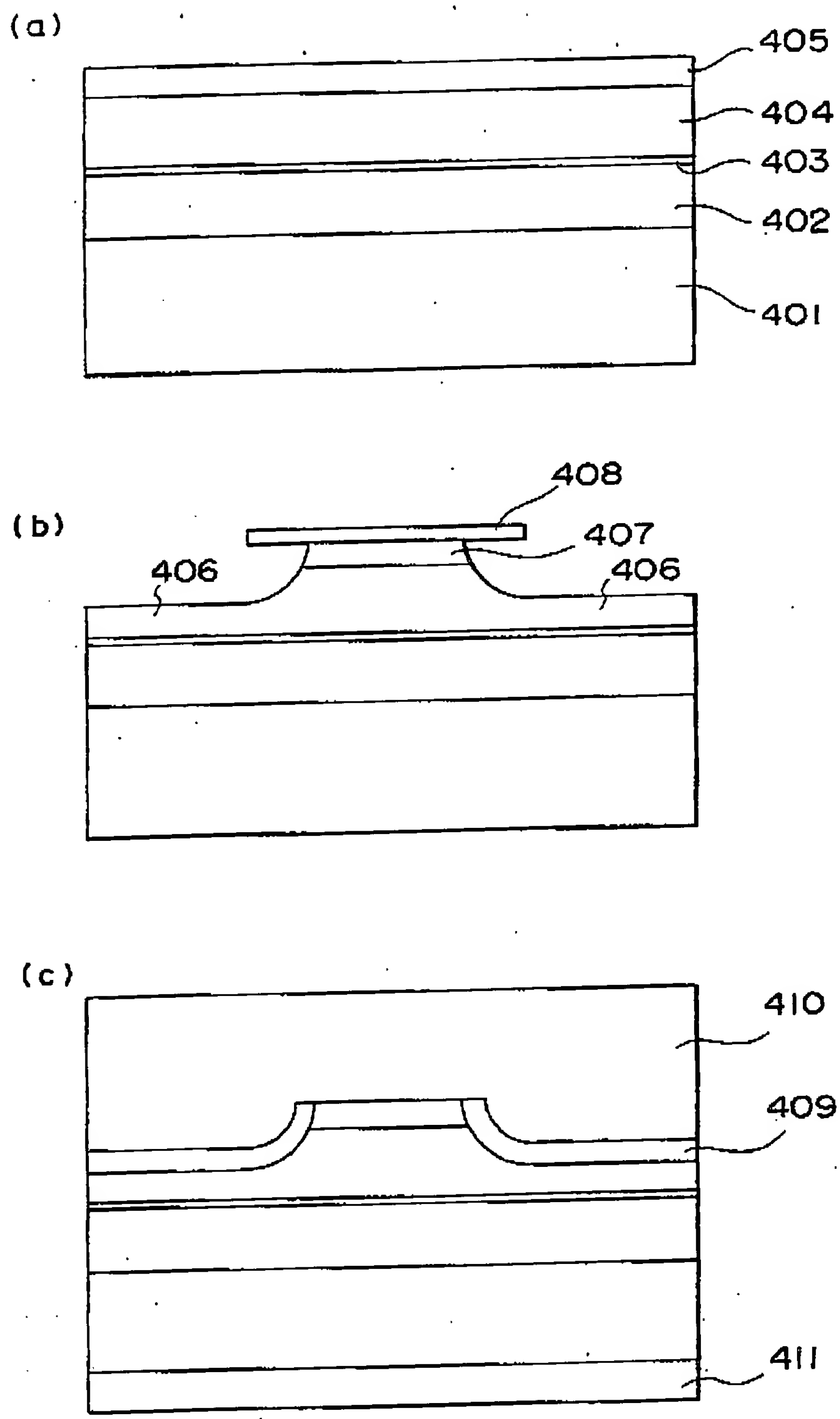
202
201
(b)
213
212
211
200
(c)
214
215

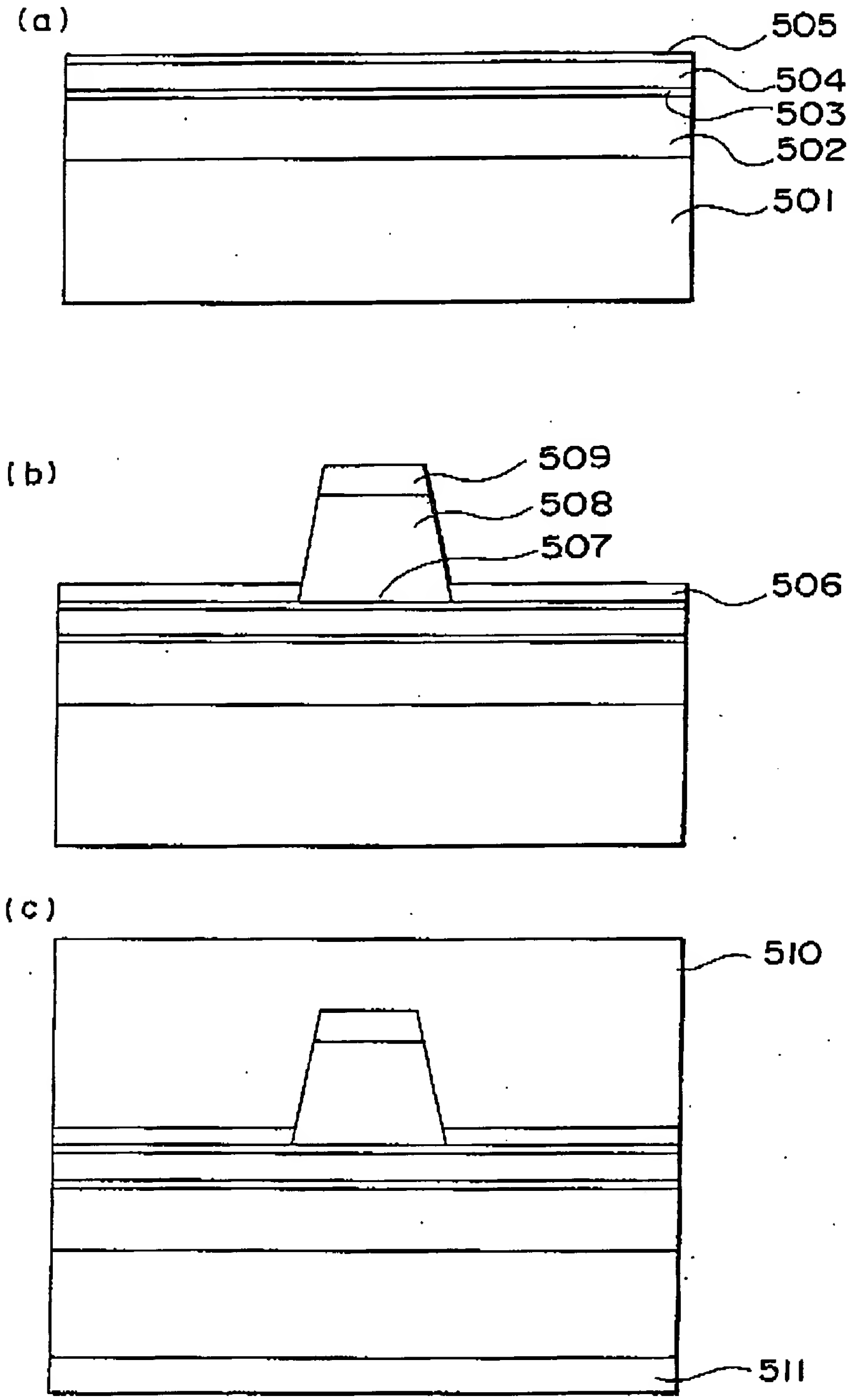
[Fig.3]



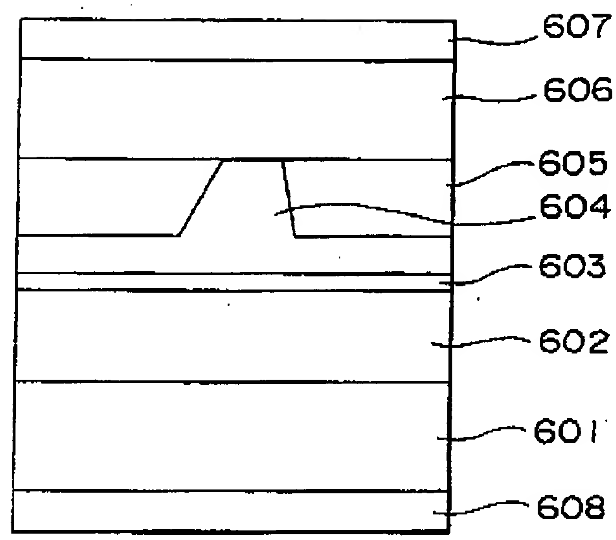
[Fig.4]



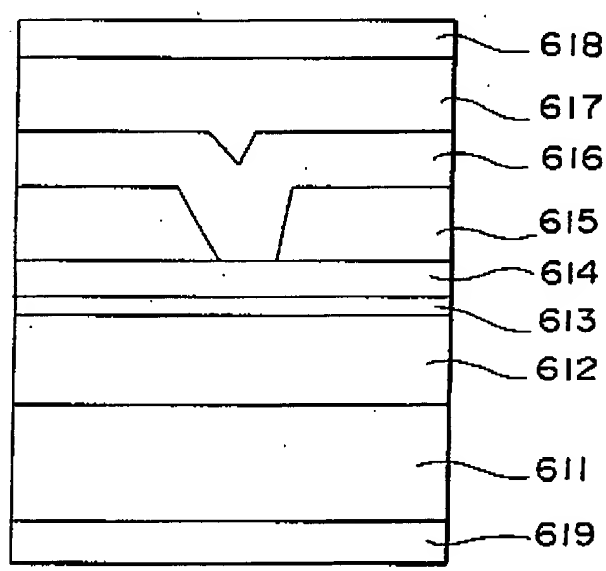
[Fig.5]



[Fig.6]



(a) Ridge



(b) Groove

[Document Name] Abstract of the Disclosure

[Abstract]

[Object] To provide a semiconductor light emitting apparatus such as a ridge waveguide type stripe laser realizing a high output operation in keeping a low operation current.

[Means to solve the problems] A semiconductor light emitting apparatus at least comprising on a substrate: a compound semiconductor layer containing an active layer; a protection film having a stripe-shaped opening formed on the compound semiconductor layer; and a ridge type compound semiconductor layer having a smaller refractive index than the refractive index of the active layer, the ridge type compound semiconductor layer being formed as to cover the stripe-shaped opening, wherein the width of the stripe-shaped opening has a shape narrower at an opening end than at an opening center.

[Selected Drawing] None